Saskatchewan Technology Enhancement Program

Mapping of Recent Cutover/Burnover Areas Using Multi-Date Landsat Digital Imagery

by

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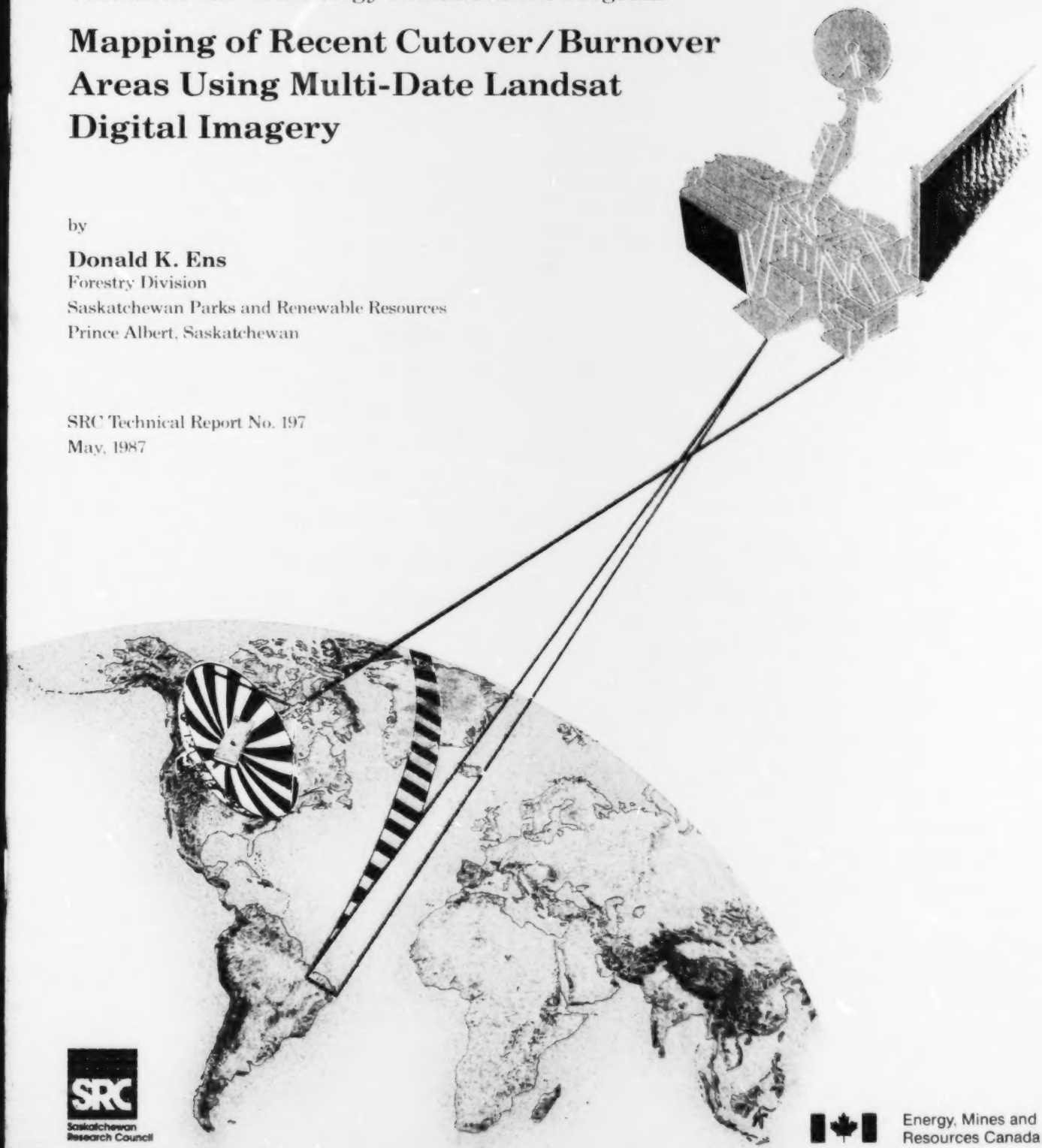

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Assessment of roads and clear cuts for the Big Sandy Lake (west side) area from Band 5 satellite image on October 8, 1984 overlayed by five themes: *Blue* - lakes; *Purple* - cutovers prior to June, 1984; *Yellow* - roads prior to June, 1984; *Green* - roads June, 1984 to October, 1984; and *Red* - cutovers June, 1984 to October, 1984.

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ABSTRACT

The feasibility of accurately updating inventory maps for cutover and burnover areas using multi-date Landsat Multi Spectral Scanner (MSS) digital data on an Aries II digital analysis system was investigated.

Supervised classification and manual theme definition methods were used in the analyzses.

Accuracy was assessed using Saskatchewan Forest Inventory maps as the source of ground data. A Geo-reference Evaluation Method (GEM) for assessment was developed to accurately assess the classification.

The geo-reference accuracy level for the Holiday Fire was 82.0% but the area accuracy level was 98.9%. However, for the cutover portion of the project, the mean geo-reference accuracy level was 39.3% because individual cutover areas were as small as 2.0 ha. The mean area accuracy level was 80.2%.

Digital mapping of burned areas using Landsat data could be used for operational applications. Although digital mapping of cut-areas by this method shows potential for the future further investigation is required.

ACKNOWLEDGEMENTS

The STEP clear-cut/burnover mapping project was done over a two year period. Completion of the project involved a great deal of research and preparation. Without training and assistance from Helmut Epp (CCRS), John Polson and Jeff Whiting (SRC) this project could not have been completed.

I would like to thank Don Pawson (Weyerhaeuser Canada Ltd.) for vital cutover information. Also, thanks goes to many of my colleagues with Saskatchewan Parks and Renewable Resources (SPRR) for their assistance.

Aerial photography and topographic maps were provided by the Forestry Division, SPRR. Prince Albert Pulpwood (Weyerhaeuser Canada Ltd.) provided 1:12500 cutting plan maps with monthly cutting activities.

EXECUTIVE SUMMARY

The feasibility of accurately updating Saskatchewan Forest Inventory Maps (FIM's) for cutover and burnover areas using multi-date Landsat Multi Spectral Scanner (MSS) digital data on computer compatible tape (CCT) and an Aries II digital analysis system was investigated.

Data from two Landsat scenes (CCT), of the same area, dated June 10, 1984 and October 8, 1984, were analyzed using with the Aries II digital analysis system. Areas which were clear-cut and burnt between these two dates were identified and assessed as to accuracy, their geographic location and area. The geo-reference accuracies were completed using a 100 dot grid.

The burnt and clear-cut areas were easily identified on the Aries II digital analysis system. There were 2355.8 ha of burnover area (Holiday Fire 1984) isolated from Landsat digital data as compared to 2330.6 ha isolated on FIM's. The resulting geo-reference accuracy level of the Landsat data delineations was 82.0%.

In the Montreal Lake area there was 118.8 ha of clear-cut area isolated in the Landsat scene as compared to 148.0 ha isolated on

FIM's. One 6.9 ha clear-cut site was misclassified from Landsat data resulting in a 0% geo-reference accuracy level. The remaining clear-cut sites had a geo-reference accuracy level of 33.8%. Other classes (roads, lakes and old cutovers) isolated from Landsat data had geo-reference accuracy levels ranging from 8.8% to 92.7%.

Project criteria must be established well in advance to ensure an accurate assessment of digital clear-cut mapping. This can be done by having:

1. The study area chosen well in advance.
2. Update aerial photography flown at the time of each Landsat digitial image.
3. An accurate assessment of the FIM's.

Cut areas within the Wapawekka Hills map sheet are primarily clear-cuts. Partial cutting (removal of a specific tree species) is a much larger mapping problem. The possibility exists that by using multi-date Landsat digital imagery, one obained during the summer months and the other during the late fall or early spring, partial clear-cuts could be mapped. The late fall or early spring image must be obtained when the ground is snow free and the hardwoods are leafless.

Current map updating procedures require that all possible update aerial photography be received. During the past five years the Forestry Division has received 50% to 70% of annual update aerial photography, some of which was incomplete or from the wrong location. Using Landsat digital data, reduces the likelihood of this occurring.

Clear-cut mapping, of the Wapawekka Hills map sheet, using Landsat digitial data and the Aries II digital analysis system required 148 hours less time than air photo interpretation at a savings of $3,630. Receipt of Landsat digital imagery, of the Wapawekka Hills map sheet (Frame 37-22), was 300 days ahead of the annual clear-cut photography at a savings of $6,920. Considering the Wapawekka Hills map sheet constituted 17% of the 1985 update aerial photography contract, purchase of a digital analysis system is economically viable.

Digital mapping of burnt areas using digital analysis of Landsat data could be used for future operational applications. However, the demonstration project was not able to assess the clear-cut mapping to an exceptable accuracy level.

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1. INTRODUCTION

The Government of Saskatchewan and the Department of Energy, Mines and Resources, Government of Canada entered into a joint remote sensing Technology Enhancement Program (TEP) in 1985. The program involved the use of a Dipix Ltd digital analysis system Aries II[1] on loan from the Canada Centre for Remote Sensing (CCRS). This equipment was installed at the Saskatchewan Research Council (SRC) which hosted the program in Saskatoon for the duration of the 2 year TEP.

The Forest Inventory Section of the Saskatchewan Department of Renewable Resources (SPRR) was requested by the SRC to become involved in a demonstration project using satellite remote sensing data. The image analysis system would be available at no cost during the duration of the project. With the potential of using the data to update existing maps and as an input into a Geographic Information System (GIS), the decision was made to do a clear-cut/burnover mapping project.

The goals for Forest Inventory's involvement in the demonstration project were to:

1. Evaluate the ease of utilizing image analysis technology.
2. Demonstrate the operational aspect of Landsat based updating under Saskatchewan conditions.
3. Demonstrate the technical applicability of this technology as part of the GIS related update scheme.
4. Produce implementation strategies for ongoing use within Forest Inventory.

Forest Inventory has utilized satellite data in the past. Since 1979 class E (over 500 acres or over 200 ha) fires were mapped onto FIM's using Landsat MSS 1:1,000,000 black and white prints. This procedure was aborted, when in 1984 fire mapping was done from aerial sketch maps using information supplied by Forest Fire Control.

1.1 Study Area

The Wapawekka Hills area is located in east central Saskatchewan between 54° and 55° north latitude and 104° and 106° west longitude (Figure 1). It covers an area of approximately 1.5 million ha (14,244 km^2) (Richard 1969) and was chosen as the study area because of extensive logging activity and road construction in the region (Polson 1987).

1) Mention or failure to mention commercial trade names does not imply endorsement or criticism by the Government of Canada or the Government of Saskatchewan.

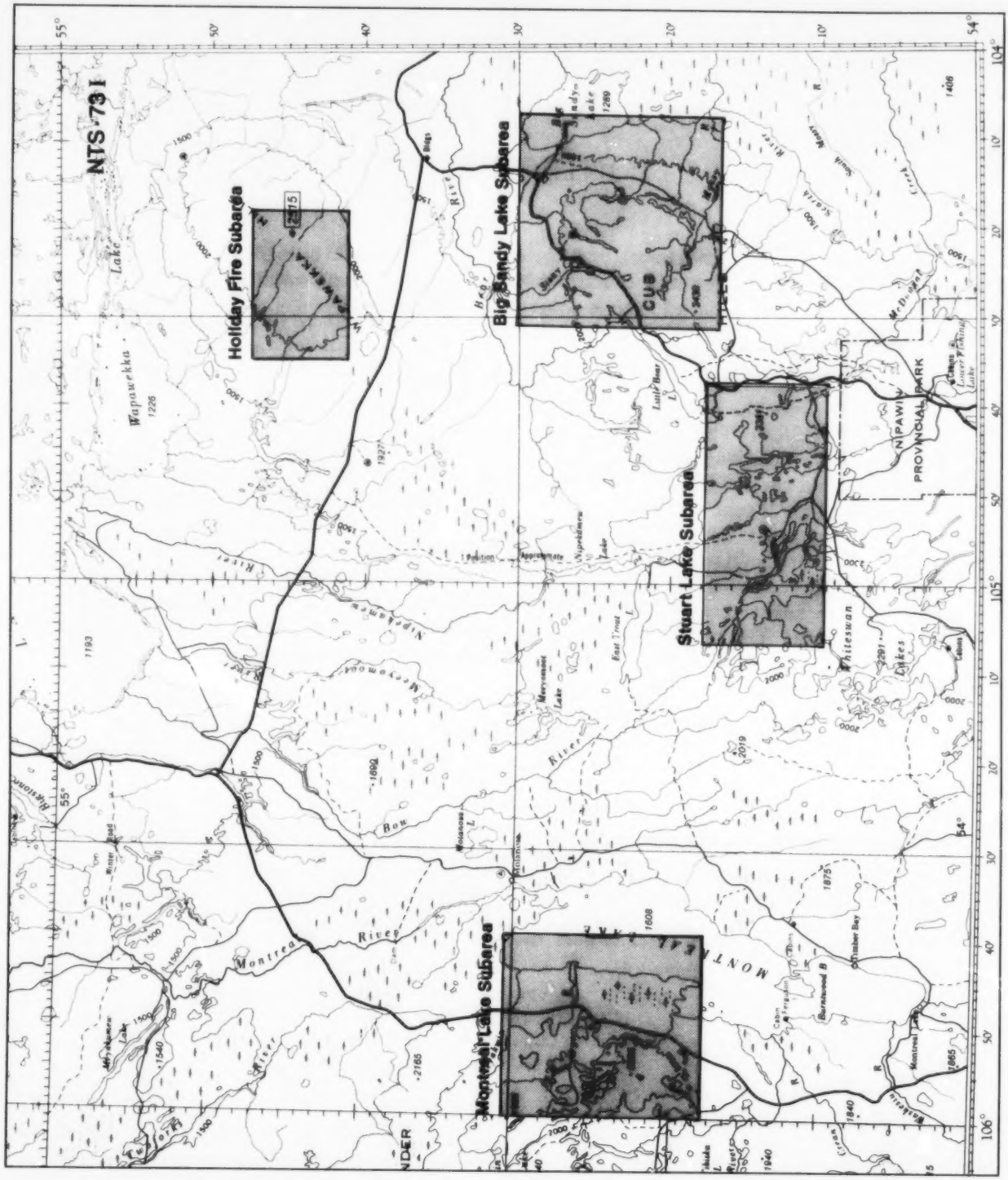

Figure 1. Wapawekka Hills map sheet (NTS-73I) Showing the geographic location of the project cutover and burnover subareas.

2. PROJECT DESCRIPTION

2.1 Objectives

The objective of the project was to map recent clear-cut and burnover areas within the Wapawekka Hills area using multi-date Landsat multi spectral scanner (MSS) digital data in computer compatible tape (CCT's) format.

The maps had to satisfy two criteria:

1. Aerial measurements of classes in hectares (ha).
2. Geo-referencing according to FIM's and 1:50,000 national topographic (NTS) maps.

After some preliminary analysis the project area was reduced to four subareas within the Wapawekka Hills map sheet. These subareas, (Figure 1) were picked to best represent the whole area.

One standard Landsat MSS CCT for June 10, 1984, (frame 37-22)

which geometrically corrected to 1:50,000 scale was obtained from the SRC. In addition, an uncorrected Landsat MSS CCT for October 8, 1984, was obtained from the Prince Albert Satellite Receiving Station. Two Landsat MSS 1:500,000 colour transparencies for May 1, 1984 and October 8, 1984 were also purchased.

2.2 Reference and Ground Data

The digital classification was completed and verified using 1:12,500 black and white (B & W), infrared (IR) and 1:25,000 modified color IR aerial photography of the subareas taken during the summer of 1983 to 1986.

Standard 1:12,500 Universal Transverse Mercator (UTM) and 1:25,000 photographically reduced FIM's provided the base for ground data.

2.3 Data Analysis

An extensive number of analysis, including linear stretches, band combinations, band ratioing and biomass index enhancements were completed to visually enhance the cutover/burnover information (Figure 2). These enhancements were initially used for visual analysis of the Montreal Lake cutover subarea.

Supervised classification and manually outlining the cutover areas were used in analyzing multi-date Landsat digital data. Subareas indicating forest cutting activity were established based on field information received from department regional staff and forest industry representatives as well as from visual interpretation of the May 1, 1984 and October 8, 1984 Landsat MSS 1:500,000 colour transparencies.

Roads and clear-cuts were manually classified using the June 10, 1984 image. Products from the supervised classification and the manual classification were then combined into a single classification. Manually outlining the clear-cuts and roads using Band 5 of October 8, 1984 was done again using an overlay of the roads and clear-cuts from the June 10, 1984 image to avoid multi-classifying between these two dates. An image to image registration for the subareas was done on the October 8, 1984 image using the geometrically corrected June 10, 1984 image as the source.

Band 7 of the June 10, 1984 image was used to establish training areas for the lake classification and the supervised classification algorithm then classified all the lakes in the study area. These were then used as reference areas in the verification and geo-referencing evaluation of all the classes as compared to existing classes on FIM's.

An image to image registration for the subareas was done on the October 8, 1984 image using the geometrically corrected June 10, 1984 image as the source.

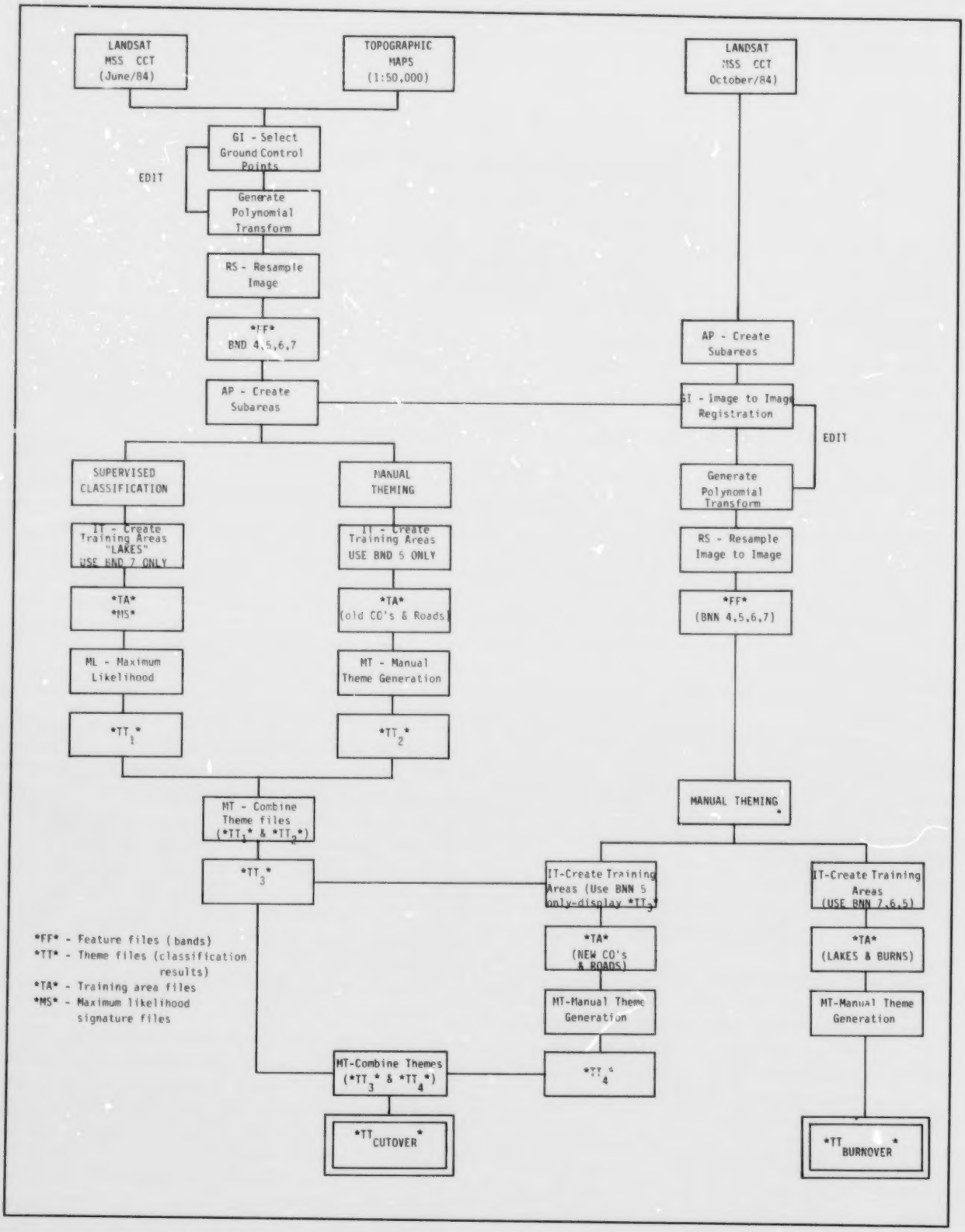
LANDSAT MSS CCT (June/84)
TOPOGRAPHIC MAPS (1:50,000)
LANDSAT MSS CCT October/84)
GI - Select Ground Control Points
EDIT
Generate Polynomial Transform
RS - Resample Image
FF BND 4,5,6,7
AP - Create Subareas
AP - Create Subareas
GI - Image to Image Registration
EDIT
SUPERVISED CLASSIFICATION
MANUAL THEMING
Generate Polynomial Transform
IT - Create Training Areas "LAKES" USE BND 7 ONLY
IT - Create Training Areas USE BND 5 ONLY
RS - Resample Image to Image
TA *MS*
TA (old CO's & Roads)
FF (BNN 4,5,6,7)
ML - Maximum Likelihood
MT - Manual Theme Generation
TT1
TT2
MT - Combine Theme files (*TT1* & *TT2*)
MANUAL THEMING
TT3
IT-Create Training Areas (Use BNN 5 only-display *TT3*)
IT-Create Training Areas (USE BNN 7,6,5)
TA (NEW CO's & ROADS)
TA (LAKES & BURNS)
MT-Manual Theme Generation
MT-Manual Theme Generation
MT-Combine Themes (*TT3* & *TT4*)
TT4
*TT CUTOVER *
*TT BURNOVER *
FF - Feature files (bands)
TT - Theme files (classification results)
TA - Training area files
MS - Maximum likelihood signature files

Figure 2. Sequencing of Aries II Tasks for Cutover and Burnover Digital Classifications.

All the classifications were combined to produce a single classification with the following classes:

1. Clear-cuts June 10, 1984 to October 8, 1984.
2. Roads June 10, 1984 to October 8, 1984.
3. Lakes.
4. Roads prior to June 10, 1984.
5. Clear-cuts prior to June 10, 1984.

Burnover areas were also delineated manually in the image analysis system using a composite image of Band 7, Band 6, Band 5 of the October 8, 1984 scene.

The delineation task used to outline boundaries of clear-cuts and burnover areas relied on a combination of visual interpretations of the digital image and 1:500,000 scale Landsat MSS multi-date colour transparencies.

The detailed sequencing of classification tasks and data files used for cutover and burnover mapping is shown in Figure 2.

2.4 Verification

A modification of the methodology described by Piper (1983) was used to determine site-specific mapping similarity.

This assessment was done using FIM's at 1:12,500 and 1:25,000 scales as the information base for comparison with the digital classifications. The classifications were geo-referenced by overlaying the FIM on the classified map. A composite map (i.e. Geo-reference Evaluation Method (GEM) map) was then created (Figure 3).

Dot counts (D), using a 100 dot/sq. inch grid, were made on the composite maps for the following classes:

a. 1984 clear-cuts.....(c1)
b. 1984 roads.....(c2)
c. Lakes.....(c3)
d. Pre-1984 roads.....(c4)
e. Pre-1984 clear-cuts.....(c5)

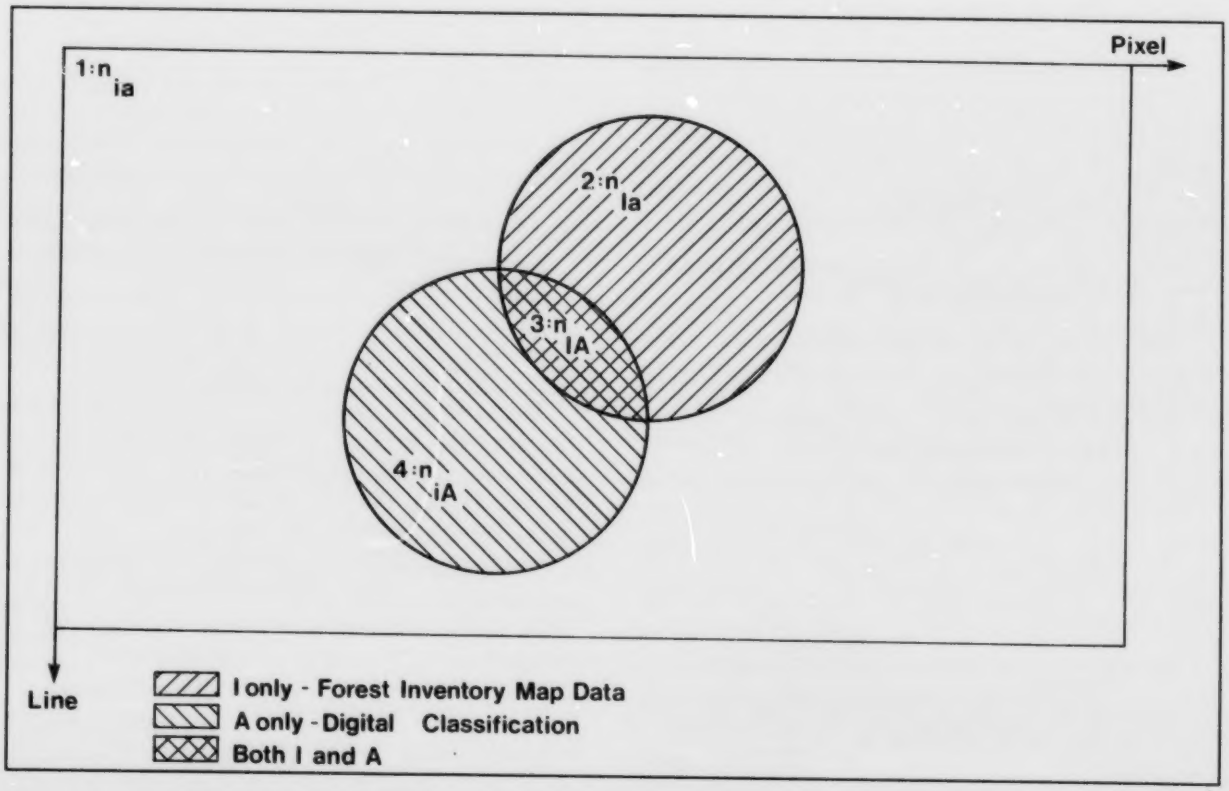

Figure 3. A GEM graph comparing Forest Inventory Map Data with Classification data

f. Holiday Fire 1984 ..... (c6)

g. Bird Dog Fire 1981 ..... (c7)

The dot counts, of the SPRR Inventory maps (I) and the digital classification (A) comparison, were used to create a GEM table.

Similarity assessments were done by comparing the geographical locations in the equation:

$$\% \text{ Similarity } (c^*) = \frac{(DIA\text{-}DiA)}{(DIA+DIa)} \times 100$$

Where: Ia is the FIM data outside the digital classification.

And: iA is the digital classification outside the FIM data.

Class areas of the FIM's were calculated using the formula:

1 dot = 0.403225 ha

Total Area c* (ha) = (DIA+DIa)(0.403225)

Class area calculations on the digital classification were done by means of the task "Classification Tabulation (CT)," a standard function of the Aries II image analysis system.

2.5 Results and Discussion

The GEM tables show the dot counts of FIM and digital classification classes and the calculated percent similarity of the classes (Tables 1 and 2). All class-area calculations for the FIM's, the digital classifications and the percent similarity of the classes are presented in Table 3.

2.5.1 Holiday Fire Subarea

The discrepancies between the FIM's and the digital classification using aerial photography indicated that;

1. Areas with living tree canopy but "burnt" ground were classified as burnover on the FIM's.
2. All areas with living tree canopy were not classified as "burned" on the digital classification.
3. Approximately 90% of discrepancies occurred within the nonproductive classification of the FIM's.
4. There was confusion in the digital classification between exposed mineral soil (fire guard), old burnovers with little regeneration and more recent burns.

The geo-reference accuracy of the Holiday Fire (Ac6) was 82.0%. This improved to 88.4% (Ac6(P)) when the perimeter of the fire was used. Similarly, when looking at the accuracy of the Bird Dog Fire (Ac7 and Ac7(P)) using its perimeter, an increase from 64.3% to 81.0% was found. In addition, another reason for the changes in accuracy is the relationship between the year of burn and the date of the Landsat CCT. Since the Bird Dog Fire burned in 1981 and the Landsat CCT date was October 8, 1984 a portion of the burn had regenerated. This explained why the area was smaller in the digital classification. Another factor of concern was the level of accuracy for the FIM's in this area. A comparison of the 1:50,000 NTS maps and FIM's indicated that the UTM grid location differed but topographical features in relation to each other were accurate to 98.2%. which explained in part the difference between the area percentage accuracy of 81.3% and the geo-reference accuracy at 64.3%.

2.5.2 Clear-cut Subareas

In order to monitor current forest activities, the Forest Inventory Section through the Map Update Unit, revises the FIM's and data bases annually. The updating procedure depends on:

1. Reports of forest activity by Department regional staff and forest industry representatives.
2. Availability of annual aerial photography of areas to be inventoried.

These factors presented numerous problems in obtaining accurate, precise ground data. In addition, various levels of human error are inherent in the determination of cutover boundaries and calculations of areas.

Extensive logging activity in the project subareas made precise clear-cut boundaries impossible to determine. Clear-cuts in these areas expand rapidly over a relatively short period resulting in boundary errors. Therefore obtaining accurate data of the most recent cutting, without using aerial photography during the satellite passes, is not possible. The available aerial photography and monthly cutting activity

Table 1.
GEM Table of Dot Counts (D) and Percentage Comparison for Montreal Lake and Holiday Fire Subarea Classes by Data Source of October 8, 1984 Imagery.

	Class Ac1	Not Ac1	Class Ac2	Not Ac2	Class Ac3	Not Ac3	Class Ac4	Not Ac4	Class Ac5	Not Ac5	Class Ac6	Not Ac6	Class Ac7	Not Ac7
Class Ic1	205	162	*	*	*	*	*	*	*	*	*	*	*	*
Not Ic1	81	*	*	*	*	*	*	*	*	*	*	*	*	*
Class Ic2	*	*	77	20	*	*	*	*	*	*	*	*	*	*
Not Ic2	*	*	67	*	*	*	*	*	*	*	*	*	*	*
Class Ic3	*	*	*	*	2030	92	*	*	*	*	*	*	*	*
Not Ic3	*	*	*	*	63	*	*	*	*	*	*	*	*	*
Class Ic4	*	*	*	*	*	*	426	119	*	*	*	*	*	*
Not Ic4	*	*	*	*	*	*	474	*	*	*	*	*	*	*
Class Ic5	*	*	*	*	*	*	*	*	655	208	*	*	*	*
Not Ic5	*	*	*	*	*	*	*	*	217	*	*	*	*	*
Class Ic6	*	*	*	*	*	*	*	*	*	*	5292	488	*	*
Not Ic6	*	*	*	*	*	*	*	*	*	*	554	*	*	*
Class Ic7	*	*	*	*	*	*	*	*	*	*	*	*	762	292
Not Ic7	*	*	*	*	*	*	*	*	*	*	*	*	84	*
% Similarity	+34		+10		+93		-9		+51		+82		+64	
% Accuracy	48		47		93		42		61		84		67	

Forest Inventory Map ..... (I)
Digital Classification ..... (A)
Classes ..... (c1-c7 incl.)
Digital Area Error Smaller than Classification Overlap ..... (+)
Digital Area Error Larger than Classification Overlap ..... (-)

Table 2.
GEM Table of Fire Perimeter Dot Counts (D) and Percentage Comparison for the Holiday Fire Subarea Classes by Data Source of October 8, 1984 Imagery.

	Class Ac6	Not Ac6	Class Ac7	Not Ac7
Class Ic6	5774	371	*	*
Not Ic6	341	*	*	*
Class Ic7	*	*	954	124
Not Ic7	*	*	81	*
% Similarity	+88		+81	
% Accuracy	89		82	

Forest Inventory Map ..... (I)
Digital Classification ..... (A)
Classes ..... (c6 & c7)
Digital Area Smaller than Inventory Map ..... (+)
Digital Area Larger than Inventory Map ..... (-)

Table 3.
Area Calculations in Hectares for the Montreal Lake and Holiday Fire Subarea Classes by Data Source of October 8,1984.

Class	Forest Inventory Map	Digital Classification	% Similarity
c1	148.0	118.8	-80.3
c2	39.1	58.5	+66.8
c3	855.6	941.8	+90.8
c4	219.8	347.3	+63.3
c5	348.0	349.0	+99.7
c6	2330.6	2355.8	+98.9
c7	425.0	345.5	-81.3

Digital Classification Area Oversized ..... (+)
Digital Classification Area Undersized ..... (-)

maps were helpful but not precise enough to accurately determine cutover boundaries. Forest Inventory aerial photography is taken between June and September every year and therefore logging activity between September and October would not be photographed until the summer of 1985. Cutting activities were mapped in the field and are of varying degrees of accuracy.

After investigating the FIM's of the clear-cut subareas, geo-reference locations were found to be grossly inaccurate which varied over a single map and also from map to map. Errors were attributed to:

1. Insufficient ground control points.
2. Scale change due to topography.
3. Use of the Radial Line Triangulation method (American Society of Photogrammetry 1952).

The Montreal Lake clear-cut subarea was mapped using our present Analytical Aerotriangulation Method (Liu 1980). An assessment of drafting accuracy was done on this new UTM map by comparing two maps prepared by different draftspersons. The level of drafting consistency was calculated to be 86.7% using the same geographic location equation used for assessing the digital classification theme classes. Because of time restraints for the project and the time involved in remapping the Big Sandy Lake and Stuart Lake subareas, no accuracy assessments were done.

After studying the Montreal Lake subarea geo-reference and area accuracy results for the classes (Ac1 to Ac5 inclusive) in Tables 1 and 3, several similarities can be seen. The two road classes (Ac2 and Ac4) have much lower accuracy levels than the lake and two clear-cut classes (Ac1, Ac3 and Ac5) in both tables. Reasons for the low levels in geo-reference accuracy are:

1. Displacement is inversely proportional to the level of accuracy because the linear width of roads is very small (i.e. displacement of 100% or 100 metres (m) results in 0% accuracy).
2. Low levels of drafting consistency for the FIM.
3. Interpretation error of edge pixels due to pixel averaging.
4. Areas are irregularly shaped, limiting definition due to image resolution.

Reasons for the lower levels of area accuracy are:

1. The pixel size (50 x 50 m) is too large for accurate and precise road definition.
2. Interpretation error of edge pixels due to pixel averaging.

Further investigation of the two accuracy assessments reveals that the lake class (Ac3) has high levels of accuracy in both assessments. This is the only class obtained by supervised classification. It should be noted however, that of all classes, (Ac1 to Ac5) the lake class (Ac3) was the largest.

There was total disagreement between the FIM (Ic1) and the digital classification (Ac1) on two individual sites of the 1984 cutovers. One site of 6.9 ha was classed as Ac1 but not Ic1. After investigation, it was confirmed as a willow run adjacent to a creek bed. This was misclassified due to the difference in reflectance values on the digital image and the 1:500,000 MSS color transparency. The second site of 7.7 ha was classed as a 1984 cutover (c1) on the FIM but not on the digital classification. Personal communications with industry personnel, confirmed that the site had been harvested between October 1985 and February 1986.

Accuracy for the two clear-cut classes (Ac1 and Ac5) varied substantially between the geo-reference and area accuracies. Although area accuracies for the two classes (Ac1 and Ac5) were reasonable, clear-cut location accuracies were poor. This was due to the following possible causes:

1. Inaccurate ground mapping of monthly cutting activity received from outside sources.
2. Image interpretation error, in particular boundary edge pixels due to pixel averaging.
3. Inaccuracy of the FIM due to control points and drafting.

These possibilities could not be substantiated because:

1. No aerial photography was available to verify ground mapping.
2. Pixel averaging was dependent on pixel size.
3. The 1:50,000 NTS maps did not show adequate features for accurate assessments of the FIM's.

It should be pointed out, that when mapping clear-cut areas and roads we are dealing with relatively small areas. Class Ac1 was made up of 11 distinct and individual sites ranging from 0.8 ha to 41.9 ha. This represented an area on the digital image of 3 pixels to 168 pixels. The average size of these sites was 10.5 ha or 42 pixels.

In Table 1, the classes derived from Landsat data are generally larger than those derived from the FIM. If only the larger classes are taken into consideration a higher level of similarity will be attained because there is a greater probability of an overlap between classes.

3. PROJECT EVALUATION AND RECOMMENDATIONS

Supervised classification of lakes using Band 7, from a mid-summer scene would be advisable, for the following reasons:

1. High water levels for the spring scene resulting in classification overrun into swamp areas.
2. Low water levels for the fall scene resulting in significantly smaller lakes.
3. Lakes freezing over or snow cover resulting in signature confusion using the fall scene.

An acceptable similarity level of 85% using Landsat MSS digital data was obtained for the Holiday Fire (Ac6). The Holiday Fire did not differ significantly between the FIM and the digital classification. The Bird Dog fire was initially discovered and mapped on satellite imagery and then checked using photography as ground data. However, the similarity level for the Bird Dog Fire was unacceptable at 60%.

For accurate identification of burnover areas, Landsat digital data should be obtained within the same year as the forest fire to avoid errors caused by regenerating vegetation (Lee and Liu 1984).

Results from the clear-cut portion of the project were inconclusive because precise and accurate ground information and a satisfactory assessment of the FIM's were unattainable. Except for the lake classification, geo-reference similarity levels for the digital classification were not satisfactory. Geo-referencing or polygon location accuracy could not be evaluated, for either the FIM's or the digital classification, other than lakes, since there is insufficient ground control data on the 1:50,000 NTS maps.

Experience gained while working on this project has convinced me that a more accurate assessment of digital analysis of satellite data would have resulted had:

1. Additional knowledge of the project area been available for ground data evaluation.
2. Aerial photography flown at the time of each satellite pass, been available.
3. The project area been reduced substantially in order to reduce costs without compromising the project objective.

These guidelines would have alleviated many of the problems, of evaluating the digital classification. Another critical factor in evaluating the digital analysis system is the accuracy of the ground information. A major problem in this project was the inability to assess the FIM regarding drafting and base mapping accuracy. Unless more current 1:50,000 NTS maps are available for the project area, polygon locations cannot be verified. An alternative is to select a new study area where more current maps are available to evaluate the accuracy.

Mapping clear-cuts using multi-date Landsat MSS digital data shows promise. However, as to the accuracy of data, the more stringent guidelines listed above must be used to ensure an accurate assessment. Also, since seasonal clear-cut areas are relatively small and irregular shaped, Landsat TM (Thematic Mapper) digital data may be an alternative. The higher resolution (i.e. 80 m for MSS and 30 m for TM) of this imagery may provide more precise and accurate clear-cut boundary definition. It will also improve the precision for road location.

Cuts within the Wapawekka Hills map sheet are primarily clear-cutting. Partial cutting or removal of a specific tree species is a much bigger problem to map. There is the possibility that by using multi-date Landsat digital data, one taken during the summer months and the other during the late fall or early spring, but snow free, partial cutovers could be mapped. The concept seems to have merit and is worth investigation.

4. PROVINCIAL INPUT AND BENEFITS

Although this project began in May 1985, with an operator's course for the Aries II system, work was intermittent and the majority of computer interactive time was in learning the system. In 1985 most interactive time was spent on a spruce budworm project using airborne digital data and coordinated by Helmut Epp and Robert Reed. Due to budget restraints from January 1986 to April 1986 no computer interactive time was possible. This meant that this project actually began in April 1986, requiring me to familiarize myself with the computer system again. An itemized account of total time spent in the program is shown in Table 4. Figure 4 indicates

Table 4.
Activity Utilization in Man Hours of Time Spent for the Duration of the STEP Project.

Month	Year	Project	Display	Workshop	Prep.	Travel	System	Post.	Research	Report	EDO	Total
May	1985	ARIES	0	40	0	0	0	0	0	0	0	40
November	1985	ARIES	0	16	0	0	0	0	0	0	4	20
Total			0	56	0	0	0	0	0	0	4	60
Percentage			0.0	93.3	0.0	0.0	0.0	0.0	0.0	0.0	6.7	
September	1985	MEIS	0	0	0	4	18	0	0	0	0	22
October	1985	MEIS	0	0	7	6	27	0	0	0	0	40
November	1985	MEIS	0	0	0	2	8	0	0	0	0	10
January	1985	MEIS	0	0	0	4	25	0	0	0	8	37
Total			0	0	7	16	78	0	0	0	8	109
Percentage			0.0	0.0	6.4	14.7	71.6	0.0	0.0	0.0	7.3	
June	1985	CO/BO	0	0	1	0	0	0	14	0	0	15
July	1985	CO/BO	0	0	0	4	8	0	5	0	4	21
November	1985	CO/BO	0	0	0	4	21	0	8	0	8	41
December	1985	CO/BO	0	0	0	0	0	3	0	0	0	3
January	1986	CO/BO	0	0	3	0	0	0	0	0	0	3
Total			0	0	4	8	29	3	27	0	12	83
Percentage			0.0	0.0	4.8	9.6	34.9	3.6	32.5	0.0	14.5	
April	1986	CO/BO	0	0	4	4	28	2	0	0	0	38
May	1986	CO/BO	0	0	0	4	29	0	0	0	0	33
June	1986	CO/BO	0	0	0	4	25	0	0	0	4	33
July	1986	CO/BO	0	0	2	4	27	0	0	0	8	41
August	1986	CO/BO	0	0	3	4	26	6	12	0	8	59
September	1986	CO/BO	0	0	0	8	50	2	13	0	16	89
October	1986	CO/BO	0	0	0	0	8	0	17	11	4	40
November	1986	CO/BO	24	0	2	10	42	0	22	26	16	118
December	1986	CO/BO	0	0	0	4	20	0	6	34	8	72
Total			24	0	11	42	255	10	70	71	64	523
Percentage			4.6	0.0	2.1	8.0	48.8	1.9	13.4	13.6	12.2	
Grand Total			24	56	22	66	362	13	97	71	88	775
Percentage			3.1	7.2	2.8	8.5	46.7	1.7	12.5	9.2	11.4	

EDO - Earned Off Prep. - Preparation Post. - Post-system

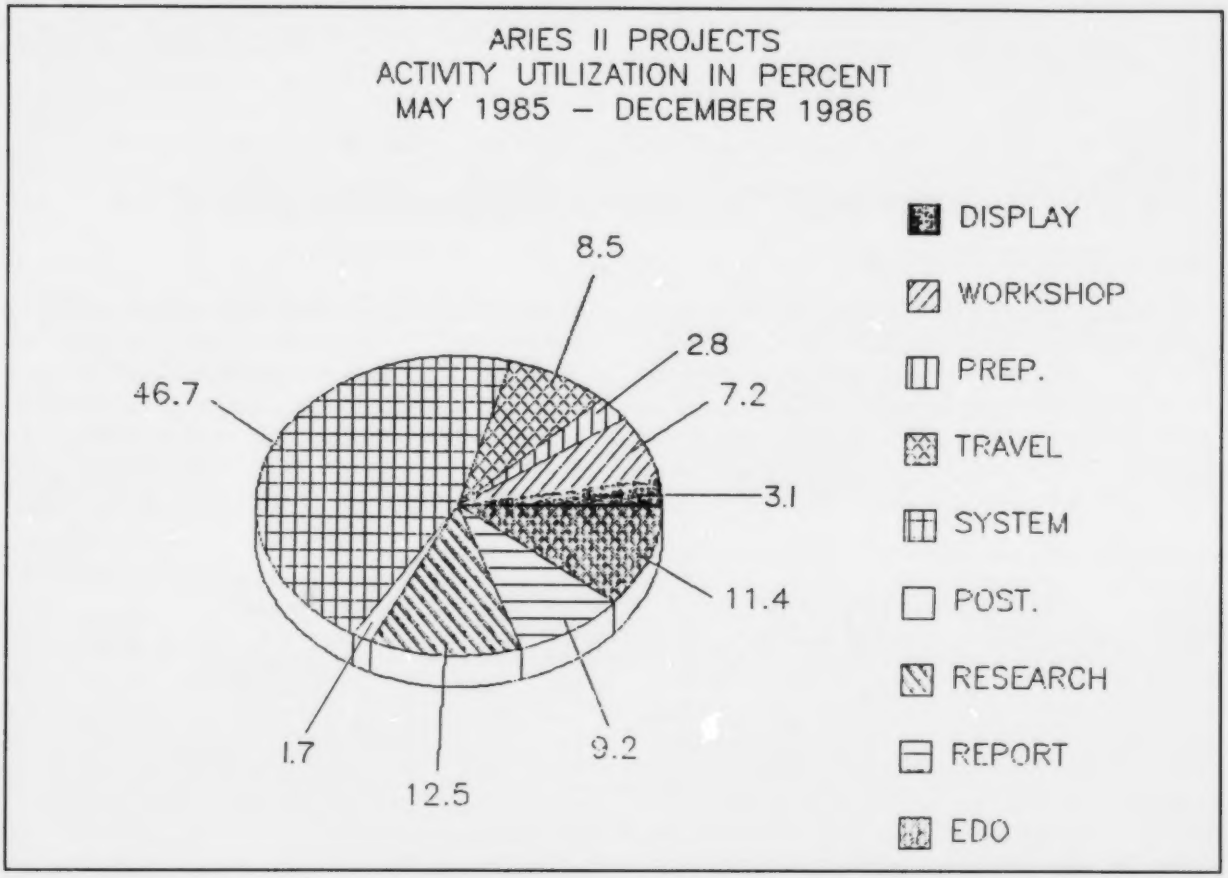

Figure 4. Activity Utilization in Percent for Aries II Projects from May 1985 to December 1986.

the relationship in percent of project activities from April 1986 to December 1986. Figure 5 shows the relationship in percent of project activities from April 1986 to December 1986. April 1986 is the point in time that I felt comfortable and confident interacting with the image analysis system. Activity percentages show that the majority of time was spent in productive computer interaction (Table 4 and Figure 5). This was an important part of the program's objective. When studying the activity utilization (Table 4, Figures 4 and 5) one of the activities is Earned Day Off (EDO). This charged time was calculated by using a weighted average of monthly activities multiplied by the number of EDO's in hours taken for the particular month.

Because the base of operation for the computer system was at the SRC in Saskatoon, additional costs for hotel accommodation and per diem were required.

The FIM update procedure is the present method for mapping forest changes due to natural and man-induced forest dynamics. Although information derived from the digital analysis system could be done through present update procedures, there are the following drawbacks:

1. Aerial photography is becoming increasingly expensive.
2. Clear-cuts may be missed from year to year because they are not reported.
3. Approximately 30-50% of update photography is not completed by contractors for various reasons.
4. There is the possibility of aerial photography being incomplete, missing portions or complete clear-cut sites.

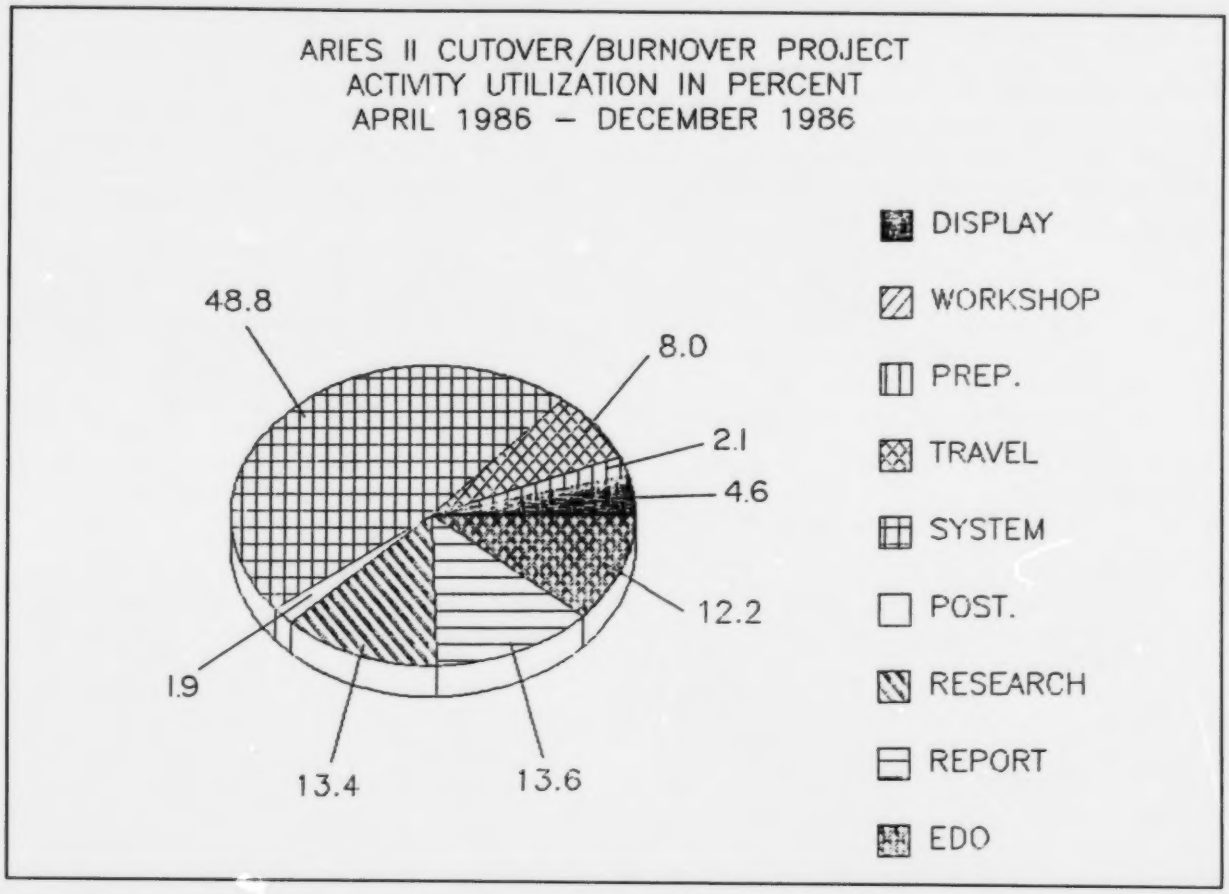

Figure 5. Activity Utilization in Percent for the Aries II Cutover/Burnover Mapping Demonstration Project from April 1986 to December 1986.

5. Aerial photography may be in the wrong location due to navigational errors.

If any of these occurred, it meant a particular map would not be updated until the following year. Using Landsat digital data, the possibility of any of these occurring was unlikely. Multi-date Landsat imagery would also alleviate the high dependency on reporting of clear-cuts by outside sources.

A comparison of the update mapping procedure and digital analysis data in terms of time and costs is shown in Table 5. The only components of time and costs used for this comparison are:

1. The update contract aerial photography and Landsat MSS CCT's.
2. Interpretation of update aerial photography and Aries II interaction based on user's salary.
3. The drafting of update interpretation polygons based on user's salary and Aries II ink-jet plotter based on paper costs of $1.00/foot.

The major cost for producing maps using the Aries II system is the initial cost of purchasing the system. The approximate cost of the Aries II system is $150,000. Based on Table 5 there would be a saving of $10,550 for the Wapawekka Hills map sheet using the Aries II system. This map sheet constituted about 17% of the 1985 aerial photography update contract. Based on these figures and accelerating aerial photography costs the purchase of a digital analysis system could be economically viable.

Using a digital analysis system, an accuracy level of 80% can be obtained for mapping cutovers and roads. Satisfactory accuracy levels were not obtained in this project because of questionable ground data. A subsequent controlled study must be done to reassess cutover mapping using Landsat digital data.

Table 5.
Comparison of the Time Required to Map June to October, 1984 Forest Activity Within the Wapawekka Hills Map Sheet Between the Forest Inventory Update Procedure and the Aries II Digital Analysis System and the Costs Involved.

Procedure	Imagery		Interpretation		Map Production	
	Time (days)	Cost	Time (hrs.)	Cost	Time (hrs.)	Cost
Update	480	$8420	120	$3350	100	$1200
Aries II	180	$1500	60	$900	12	$40
Difference	300	$6920	60	$2450	88	$1180

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